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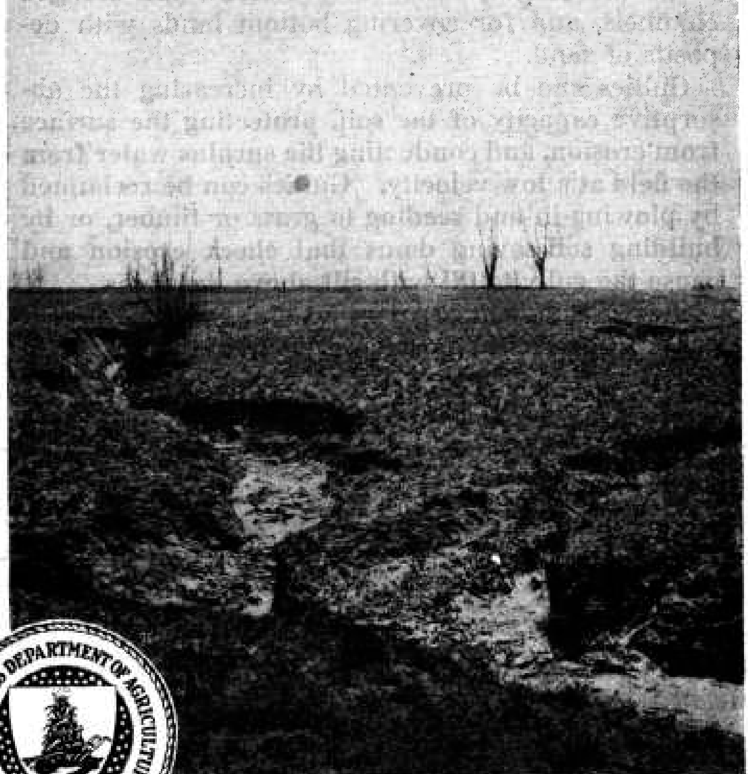
GULLIES

HOW TO CONTROL AND RECLAIM THEM



GULLYING occurs in every State in the Union. Besides ruining fertile land, gullies interfere with farm operations, undermine buildings, encroach on public highways, endanger the life of stock, and often mar the beauty and lower the market value of a farm. They are also largely responsible for filling up reservoirs, streams, and dredged channels, and for covering bottom lands with deposits of sand.

Gullies can be prevented by increasing the absorptive capacity of the soil, protecting the surface from erosion, and conducting the surplus water from the field at a low velocity. Gullies can be reclaimed by plowing-in and seeding to grass or timber, or by building soil-saving dams that check erosion and cause the gully to fill with silt above the dams.

It is recommended that this bulletin be read in conjunction with Farmers' Bulletin 1669, Farm Terracing.

Washington, D. C.

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GULLIES; HOW TO CONTROL AND RECLAIM THEM[1]

By C. E. RAMSER, *Senior Drainage Engineer, Bureau of Agricultural Engineering*

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OCCURRENCE OF GULLIES

GULLIES occur in every State. In the South damage to farm land is prevalent because the rainfall is heavy and much of the land has been devoted year after year to the production of row crops, such as cotton, corn, and tobacco.

FIGURE 1.—Gully encroaching on farmer's premises which, unless controlled, will undermine the buildings. Near Alma, Wis.

Gullies are also common in the North and frequently cause serious damage.[2] In a typical case an 80-acre farm, on which there were no

[1] This bulletin is based in part on studies conducted in cooperation with the Bureau of Chemistry and Soils.

[2] For a discussion of the damage done by soil erosion see Department Circular 33, Soil Erosion a National Menace.

gullies 35 years ago, has been practically ruined for farming due to the formation of a large gully with many branches. This gully grew to a depth of 15 to 20 feet and was 30 to 60 feet wide. Expensive concrete structures were required to prevent it from crossing two highways.

FIGURE 2.—Road culvert and concrete drop inlet built at great expense to prevent gully from crossing the highway. It is shown partly undermined and later was washed out. Near Alma, Wis.

RESULTS OF GULLYING

The greatest damage caused by gullies is the carrying away of fertile soil. Other bad features are:

They can not be readily crossed by teams and farm implements.

They grow rapidly, if unchecked, and often extend through a farmstead, undermining and necessitating the removal of farm buildings. (Fig. 1.)

They encroach upon public highways and make travel unsafe.

They extend across farm roads, undermine culverts and similar structures (fig. 2), often necessitating the building of bridges.

They cause the silting up of reservoirs and natural channels, and of channels dredged at great expense. (Fig. 3.)

FIGURE 3.—Channel nearly filled with sand washed from adjoining hills, requiring dredging at great expense to provide drainage for the bottom lands. Gwinnett County, Ga.

They carry sand washed from hills and deposit it on rich bottom land, making it unproductive. (Fig. 4.)

They give a farm an unsightly appearance, reducing its market value and that of adjoining farms.

They endanger the life of stock that graze near the edges of undermined banks.

CAUSES AND TYPES OF GULLIES

Gullies are caused by erosion due to water collecting and flowing at a velocity sufficient to move and carry away soil particles.

FIGURE 4.—Part of cornfield covered with sand washed from hillside gullies, the result of one heavy rain. Near Jackson, Tenn.

HEAD EROSION

When plants and soil are unable to retain all of the rain that falls on rolling or hilly land the surplus flows over the surface to a drainage channel at the foot of the slope. If there are no draws or depressions the water travels over the surface to the foot of the slope in broad, thin sheets. Where depressions exist, however, the water from the surrounding area is collected and forms a stream with power to wash away the soil. The power to erode increases as the stream increases in size and velocity, and if the depression is not protected from erosion by grass or other means a gully is formed which is enlarged by each succeeding rain.

FIGURE 5.—The beginning of a gully down a hillside. It was caused by the passing of a wagon once down the slope, and if not controlled, is destined soon to be a large gully. Near Jackson, Tenn.

Gullies may also be started by artificial means such as the track of a wagon driven down a slope when the ground is soft (fig. 5), or by dragging a plow down a slope. Mole holes and cattle paths frequently cause the formation of gullies. One of the most common ways in which gullies are started is by plowing or cultivating straight up and down a slope. (Fig. 6.) A dead furrow extending in the direction of the slope may rapidly develop into a gully.

DITCH EROSION

Where head erosion occurs on the upper part of a watershed it makes channels for the rapid removal of the excess water from the field slopes and delivers the water in large volume to the natural drainage channels at the foot of the slopes. The capacity of these

FIGURE 6.—Gullies on a hillside due to running cotton rows directly up and down the slope. Near Jackson, Tenn.

channels is overtaxed by the quick delivery of the water from all parts of their watersheds, and the result is that the channels are greatly enlarged by the erosive action of the water. This enlargement continues until huge gullies are formed, often 15 to 20 or more feet deep. Enlargement caused by ditch erosion is very rapid on the upper parts of the watershed, where the slopes are comparatively steep. Ditch erosion generally decreases downstream as the fall of the channel becomes less, and the fall often becomes so slight that silting instead of erosion occurs, particularly where the channel extends across a wide bottom and discharges into another stream.

WATERFALL EROSION

Waterfall erosion, which is responsible for many of the deepest gullies or chasms, is caused by water falling over the edge of a gully or ditch bank. The falling water undermines the edge of the bank, which caves in, and the waterfall moves upstream. This undermining goes on rapidly, if the surface soil is underlain by sand or easily eroded subsoil saturated with water.

In this manner gullies often start in the banks of natural watercourses which have been eroded to a great depth. They extend back into the land slopes and grow deeper up the slope, often attaining depths of 50 to 60 feet. As they extend backward and cross tributary watercourses or natural depression, waterfalls are in turn formed in their sides, and branch gullies develop. (Fig. 7.) This branching may continue until a network of gullies covers the entire watershed. Gullies formed by waterfall erosion may extend back through almost level land. Their growth is dependent upon the size of the drainage area furnishing water and not upon the slope of the land. They sometimes grow at the rate of 30 to 50 feet in a year, depending upon the amount of rainfall, the drainage area, and the character of the soil.

FIGURE 7.—Gully branching off from main gully and advancing up a hillside, growing in depth as it eats its way. Note the undermining of the bank at its head. Near Alma, Wis.

FIGURE 8.—Gullied area on moderate slope, growing larger each year. A type of gullying due largely to freezing and thawing, followed by heavy rains. Near Middletown, Tenn.

EROSION BY FREEZING AND THAWING

Another type of erosion, common throughout the South, is caused by alternate freezing and thawing followed by heavy rains. It works on all slopes of a gully bank and does not necessarily follow watercourses. Owing to its ability to extend in all directions, erosion

of this type expands over wide areas, its direction of growth not being dependent upon the slopes of a field. It progresses rapidly, particularly in silty loams and clay loams. (Fig. 8.)

PREVENTION OF GULLYING

Many large gullies would never have been formed if steps had been taken to check them in the beginning. Gullies from head erosion could be prevented if each square foot of the field slopes could be made to absorb all of the rain that falls upon it. The water would then be fed slowly to the main water course below. Means employed to this end are: increasing the humus content of the soil, deep plowing, the use of cover crops, proper crop rotation, contour plowing, and tile draining.

It is, of course, impossible to make any soil absorb all of the water from the heaviest rains, and in order to prevent erosion the excess water should be conducted from the field at a low velocity. This can be most effectively done by terracing the land. Farmers' Bulletin 1669 covers in detail the practice of terracing farm lands.

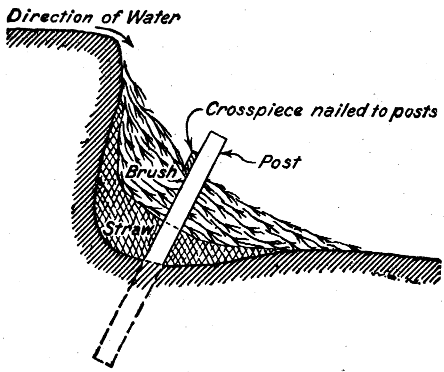

FIGURE 9.—Method of checking erosion and undermining at the head of a gully with brush and straw held firmly in place[3]

CHECKING HEAD EROSION

No matter what method is adopted for control and reclamation of a gully, it is first of all important to check erosion at the head of the gully. Where possible it is advisable to intercept the water before it enters the head of the gully and divert it into a natural watercourse nearby. In shallow gullies, 3 or 4 feet deep at the upper end, head erosion can be checked quickly by building a low obstruction or dam close to the head of the gully. A fill of soil will occur between the dam and the head of the gully, the drop of the water will be reduced by the height of the dam, and the erosive and undermining action of the water will be greatly decreased at the head of the gully. If the gully is deep, a comparatively longer time will be required to fill it, whatever method is employed, and during the filling some temporary means should be employed to stop head erosion and undermining.

One method of checking head erosion that is widely used in Iowa consists in placing brush and straw in the head of the gully and fastening it down as shown in Figure 9. Posts should be set deep in the ground, close to the bank of the gully, and 2 to 3 feet apart. Fence posts can be used. A layer of straw is first thoroughly packed around the posts and against the eroded and undermined part of the gully bank. A few branches are laid crosswise and interwoven between the posts to hold the straw in place. Brush is packed down

[3] From Bul. 74 of the Iowa State College agricultural extension department.

over the straw, the tops of the branches extending nearly to the top of the bank, and is held in place by the crosspiece nailed to the post as shown in Figure 9. This affords a place on which the water will fall without causing erosion and stops the progress of the gully by preventing undermining until the gully is filled by other methods.

In Figure 10 is shown a sheet-metal flume at the head of a gully. The water is conducted into the flume between earth dykes. This flume is intended for use until the gully can be filled by means of dams constructed below. Some sort of protection is generally required at its lower end to prevent washing.

NATURAL CONTROL AND RECLAMATION

Nature's method of controlling gullies is to prevent erosion on the surface by the growth of vegetation and to hold the soil together by the plant-root systems. The dead organic matter which accumulates on the surface of the soil from year to year prevents surface

FIGURE 10.—Water conducted into head of gully by levee and a sheet-metal flume, the left-hand levee not yet built; brush and stone to be placed at the lower end of the flume. Near Alma, Wis.

erosion and absorbs much of the rainfall. Nature can control gullies, but the natural process of reclaiming them after they are formed is very slow.

If eroded and badly gullied land is abandoned a volunteer growth of some sort usually springs up. The kind of growth depends upon the locality. Wild native grasses, weeds, shrubs, and trees are the most thrifty and the best for rapid and permanent control of gullies. In some sections pine trees spring up spontaneously over eroded areas and in conjunction with weeds and grasses form a good natural control. Wild honeysuckle grows and spreads rapidly on poor soil and is very effective in controlling erosion, but because of its tendency to spread some farmers prefer other plants. Large gullies with steep, caving banks are the most difficult to control by

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natural means. They generally continue to enlarge for many years after the land has been abandoned for farming. Large trees figure prominently in the control of such gullies. Plants which supply both nitrogen and humus to the soil are best for natural control, for they will give to the land reclaimed for farming essential elements of fertility. Sweetclover and black locust trees furnish nitrogen to the soil, and have large branching root systems which are effective in the control and reclamation of gullies.

In Pendleton County, Ky., large eroded areas of abandoned lands have been reclaimed by the volunteer growth of sweetclover. When sweetclover made its first appearance in the county it was regarded as a weed of the worst kind because of its big root system and prolific growth. Many farmers who formerly devoted much time to ridding their places of this plant now gather the seed and sow it on their worn-out gullied lands, having noted the large crops grown on abandoned lands reclaimed by the volunteer growth of sweetclover.[4]

PLOWING-IN AND SEEDING GULLIES

Plowing-in and seeding is a simple though sometimes rather expensive method of reclaiming gullies. It is applicable to both large and small gullies with small drainage areas and has been successful in all sections of the United States.

Small gullies (1 to 3 feet deep) with no well-defined drainage areas should be entirely filled. They can be first partly filled with manure, straw, corn stalks, or small brush, which should be covered with a foot or more of dirt by plowing and scraping in the edges of the gullies. If it is not desired to cultivate the hillside, seeding the land and keeping it in meadow or pasture, or devoting it to the growth of timber will largely prevent erosion. If the land is to be cultivated it should first be terraced.

For shallow gullies, or deep gullies with gently sloping banks, the plowing is begun in the bottom or as near the bottom as possible. The dirt is thrown toward the center of the gully from both sides. The plowing is done in the same way as in breaking land and is continued a few furrows beyond each edge of the gully. To push the dirt toward the center of the gully, an ordinary road drag or steel ditcher can be used to advantage after each furrow. If the upper part of the side slope is steep it is cut down and rounded off with a mattock. In case sufficient dirt has not been moved into the gully after the first plowing, the plowing may be repeated until the desired filling is obtained. If the side slopes are too steep for a team to walk on, a chain hitch to the plow will permit plowing on the slope when the team is on the edge of the gully.

In plowing-in a deep gully with nearly vertical banks the team is made to walk as close to the edge as possible, and the upper edge of the bank is plowed into the gully. The second furrow cuts the first deeper and the third takes another slice below the second. A long chain is attached to the plow so that it can be operated down in the gully while the team walks along the upper edge.

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[4] For information on sweetclover see Farmers' Bulletin 1005.

After the first line of furrows has reached as far down as the plow can be operated, the process is repeated by starting at the top again, the object being to reduce the side slope. If the gully is not too deep the side slopes can be so reduced in a short time that the team can walk up and down them and across the gully. The team and a scraper can then be used to reduce the side slopes still more and to distribute part of the soil over the bottom of the gully, or the method described for gullies with gently sloping banks can be employed.

The freshly plowed earth on the sides and bottom of the gully affords a good seed bed. Grasses should be sowed or trees planted to hold the soil in place, and temporary dams of some material such as brush or straw should be built to catch the loose soil that might otherwise be washed away by heavy rains. Some of the grasses that can be used for this purpose are Bermuda grass, orchard grass, bluegrass, redtop, sweetclover, and Lespedeza. Every locality has certain grasses best suited to it. Bermuda is probably one of the best grasses for southern conditions, and provides excellent pasture for stock. Wild honeysuckle grows luxuriantly in the South on almost barren soils. A more rapid growth can be obtained in gullies by supplying fertilizer elements in which the soil is deficient. Manure will provide these for most soils. Sorghum is very effective in controlling erosion in gullies.

On the State agricultural experiment station farm near Holly Springs, Miss., some very badly gullied lands were reclaimed by the plowing-in and filling method. Areas of the type shown in Figure 8 were reclaimed on this farm. The filled-in gullies were seeded to Lespedeza or to Bermuda grass. Most of the land was then terraced to keep the water from flowing down through the gullies. In some instances, on this farm and others, dynamite was used to advantage in leveling down and filling gullies. The banks were broken down and blown into the ditch by placing explosives in a row of holes 2 to 4 feet from the edge of the gully, depending upon its depth, or in a row of horizontal holes in the sides and near the bottom of the gully. The first method is preferable for gullies with broad sloping banks and the second for gullies with high, steep banks.

TILING AND PLOWING-IN GULLIES

After plowing-in, further erosion in a gully is sometimes prevented by the use of tile. Large tile, the size depending upon the area drained by the gully, is laid down the middle. The water may be conducted into the tile from a catch basin at the upper end of the gully or by building a dam across it and extending the tile through the dam.

PLANTING TREES TO CONTROL GULLYING

In many localities gullying has been effectively checked by planting trees. This method is particularly adapted to land that is very steep or that has been gullied so badly that the cost of reclaiming it for pasture or cultivation would be prohibitive. In addition to building up the land the wood lot thus formed may be made a paying

investment to the farmer, furnishing firewood and small timbers. In the South the black locust is an excellent tree for this use. North of the Kansas-Nebraska line it is very commonly attacked and destroyed by the locust borer. The black locust is a legume and builds up soil by contributing nitrogen. It has a large interlacing root system which holds the soil particles together and prevents washing. It grows to the size of a good fence post in about 10 years and is especially adapted for posts on account of the durability of its wood. Other trees [5] that are used in different sections for planting on eroded areas are pine, catalpa, yellow poplar (tulip), walnut, and red and black oak.

In planting trees on gullied and eroded areas the best results are

FIGURE 11.—Gully formerly deep with steep banks reclaimed by locust trees and brush dams. Near Martin, Tenn.

obtained by plowing the entire gully and thoroughly disking or harrowing the ground. The trees should be set out in rows 5 to 6 feet apart in deeply plowed furrows. The rows on the sides of the gully should be laid out approximately on the level, as the trees should be cultivated the first year by throwing the dirt from each side toward them. Less washing occurs where the rows closely follow the contour of the ground. It is very important that the soil bed be properly prepared, as this will promote a rapid growth of the trees, and they are less likely to die at the start.

The best results are obtained where some kind of dam is built across the gully to catch and hold any soil that otherwise would be carried away in the drainage water. Brush dams are commonly used for this purpose; before they rot out the tree root systems will have extended so as to prevent serious washing. (Fig. 11.) It is

[5] For a list of trees adapted for use in the various sections of the United States the reader is referred to Farmers' Bulletin 1177, Improvement of Farm Woods.

also a good plan to sow grass seed between the trees after setting them out.

This grass should not be pastured, at least not closely, because close pasturing greatly retards reclamation. Where a thicket of locust is desired and the trees are not needed for posts, they are sometimes cut down after the first year; this causes sprouts to spring up between the tree rows and provides a dense growth which is effective in checking erosion.

Willows have often proved effective in checking erosion in a gully. They should be set out at intervals in rows across it. They require an abundance of water for rapid growth.[6]

SOIL-SAVING DAMS FOR GULLIES

The common method of controlling or filling in and reclaiming gullies consists of building soil-saving dams across them.

Temporary dams are built of stakes, brush, straw, logs, loose rock, or woven wire; permanent dams are built of earth, masonry, or concrete. Their cost is often very small if materials available on the farm are used. Stones are a nuisance in a field, but are excellent material for dams. If no stones are available, timber and brush may be plentiful and log and brush dams may be built at small expense. Where none of these materials is available straw may be plentiful and can be used for low dams, the straw being held in place by stakes. Woven-wire fencing costs little and is excellent material for low dams.

Most temporary dams are porous; that is, when first built they permit the water and part of the silt to pass through them. They are gradually built up as the spaces are filled with trash and soil brought down by the water and are never subjected to the heavy pressure exerted on a water-tight dam by the water ponded above.

Most permanent dams are water-tight, and in order to pass from the upper to the lower side of the dam the water must either flow over it, be diverted around it, or carried through it by a conduit. If the water is to flow over the dam, a spillway of nonerosible material is provided, generally at the middle of the dam, and should be wide and deep enough to remove the greatest flow of water expected. If the water is to be diverted around the ends of the dam, it is generally made to flow over firm, sodded ground. Sometimes a shallow channel is dug to carry the water around the end of the dam and empty it into the gully at a considerable distance below. If the water is to pass through the dam, it is carried in a pipe.

The inlet consists of a vertical pipe connected to a horizontal line of pipe extending through the dam along the bottom of the gully. The top of the inlet is lower than the top of the dam and the water ponded above does not flow out until it reaches the top of the inlet pipe. The pond above the dam practically forms a sedimentation basin, as the silt in the water settles to the bottom and in time fills the gully to the top of the inlet pipe. Such a dam is sometimes called the drop-inlet soil-saving dam, from its vertical inlet pipe.

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[6] For information on setting out and caring for trees the reader is referred to publications of the Forest Service, U. S. Department of Agriculture.

It is known throughout the State of Missouri as the Adams soil-saving dam, as it is said to have been originated by J. A. Adams, a pioneer farmer of Johnson County, Mo. Mr. Adams has five of these dams on his farm; all of them have successfully filled and reclaimed gullies.

LOOSE-STRAW DAM

In some localities stacks of straw are frequently used to form dams across deep, wide gullies. Where the threshing is done near a large gully the straw can be placed directly in the gully by the machine. This method is very successful for large gullies with very small drainage areas and little fall. Where much water flows through a gully the straw dam is likely to be washed out or a channel washed around the end. The chances of failure can be reduced by building the dam high at the sides and low in the middle, so that if all the water does not seep through the straw it will flow over the top of the dam at the middle.

The first straw dam should be built near the mouth of the gully so as to catch all the soil that is being carried away by the water. At the same time provision should be made to stop waterfall erosion at the head of the gully. After as much soil has been filled in above the first dam as it is thought can be held by the sod seeded there when the straw rots out, another straw dam should be built a short distance farther up the gully, and then another until the gully is filled in as desired. This is a simple and easy method of reclaiming certain types of gullies, if a large quantity of straw is available.

Further washing of small shallow gullies is sometimes prevented by filling them with loose straw during the fall and winter. The water percolates through the straw, the silt being retained. In the following spring the partly rotted straw is generally covered by plowing-in the gullies, thus adding to the fertility, and increasing the humus content and the absorptive capacity of the soil. On steep slopes or where the gullies carry much water, this method is not a success, since the straw is usually carried to the foot of the slope by the force of the water.

SOD DAM

Sod dams are often successfully employed to check erosion in small gullies draining one-quarter acre or less on moderate slopes. To get sod well started it is necessary to place it above a small dam of brush, rock, or other inexpensive material. Perhaps the best way is to place the sod in loosely woven grain sacks, tie these up and build them into small dams in the gully. Usually the filled sacks are placed end-to-end across the gully. Each dam should be lower in the middle than at the sides of the gully so as to permit the water to flow over without washing around the ends. Sufficient soil should be placed between and around the sacks—particularly on the upper side—to prevent water percolating through the dam. Usually a good sod growth has developed before the sacks are rotted out. Native grasses which are hardiest in the locality can be used for this purpose.

WOODEN-STAKE DAM

A cheap method of filling-in and reclaiming gullies of moderate slopes and small drainage areas consists in driving several rows of stakes across the gully in checkerboard fashion. The stakes should be 3 to 7 feet long with a diameter of 2 to 4 inches at the upper end. The rows should be from 6 inches to 2 feet apart, and the stakes the same distance apart in the rows. The stakes should be driven into the ground until the tops extend 8 to 20 inches above the surface; the larger and longer the stakes the greater may be the intervals. The rows of stakes should extend across the gully and up the sides as high as water ever reaches, and the tops of the stakes on the sides of the gully should be at least 1 foot higher than the tops of the stakes in the middle. The stakes may be made of any available hard wood. When stones are available the dam can be made more substantial by filling in the spaces between the stakes with them, as shown in the three lower dams in Figure 12. Where stone is not available the ability of the stakes to check and hold silt can be increased by filling in straw between them. A series of such dams should be built along the entire length of the gully, the distance between them being such that each dam will cause a deposit of silt extending to the next above. As soon as the filling in above the first series of dams is completed other dams should be built between the first ones and the filling-in process continued by additional dams until the gully is filled as desired.

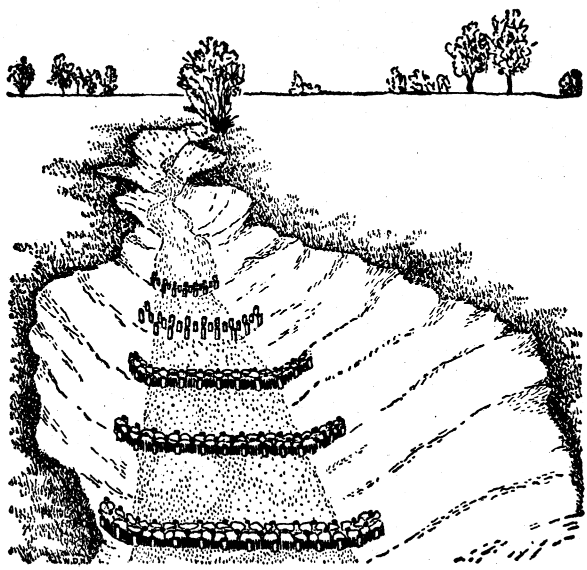

FIGURE 12.—A series of stake dams in a gully. The spaces between the stakes in the three lower dams are filled with stones

BRUSH DAM

In localities where timber and brush are abundant excellent results have been obtained by the use of brush dams. The methods of building these dams differ somewhat in different sections of the country. In hillside gullies where the flow of water is small the dams are commonly built of loose brush, sometimes weighted down with logs or rocks. Where the flow is sufficient to overtop the dam the brush can be held down by crosspieces or wire and stakes, or the dams are sometimes built by weaving brush into a row of stakes

across the gully. Successful results can not be obtained by simply dumping brush into the gully.

In reforesting gullied lands in Tennessee, the State forester has used loose-brush dams extensively. The dams are built to catch and hold soil in the gullies until the planted trees are able to hold the soil against erosion.

In building these dams, trees are first dragged to the site of the gullies, and the branches are cut off. Several layers of branches with the tops pointing downstream are first laid for the foundation of the dam. This is to prevent slipping, as the greater part of the dam is built with the branches extending crosswise of the gully. The dam is built up by laying the branches close together across the gully, but occasionally a layer of branches is placed with the tops pointing upstream and extending beyond the face. When these branches become covered with silt they tend to hold the dam more securely in place and tie the brush together. After the dam is built about 3 feet high, logs furnished by the trunks of the trees are laid across on top of the brush lengthwise of the dam to hold it down. The dams are built lower in the middle so that the water will flow at that point and prevent washing around the ends. Dams built in this manner can be used only where the drainage area of the gully is very small; where there is a large flow of water they are likely to be floated away or washed out. (Fig. 11.)

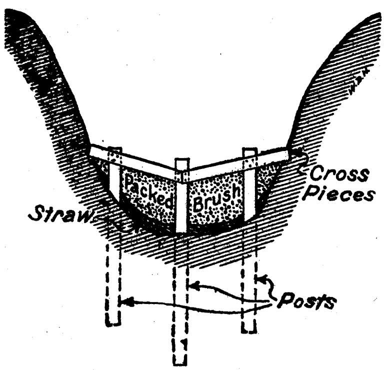

FIGURE 13.—Straw and brush dam held in place by crosspieces and posts [7]

Where the water in a gully is sufficient to overtop a brush dam it is necessary to anchor the dam more securely. M. H. Hoffman and A. W. Turner, formerly of the Iowa State College extension department, who have had wide experience in building dams of this type, recommend the following method for building dams that are at times overflowed. The bottom and sides of the gully for a distance of 4 to 10 feet are covered with a layer of straw that will be from 4 to 6 inches deep after being pressed down by the weight of the dam. The brush, with the butts pointing upstream, is laid close together on the straw and thoroughly tramped down, the fine brush being placed at the bottom and the coarser on top. The packed brush is held in place by crosspieces nailed to fence posts set in the line of the dam across the gully as shown in Figure 13. It is important that the fence posts be set well in the ground, usually not less than 4 feet deep. The figure shows the middle of the dam lower than the sides so that the water will not have a tendency to wash around the ends.

Another method of anchoring such a brush dam is to drive several rows of stakes across the gully, the rows 2 feet apart and the stakes 1 foot apart in the row. The gully is partly filled with brush before the stakes are set in place and lightly driven in. Sufficient brush to

[7] From Bulletin 77 of the Iowa State College agricultural extension department.

complete the dam is then placed and heavy wire is stretched along the rows of stakes and fastened to them. Finally the stakes are driven in until the wire holds the brush firmly in place, the dam being made lower at the middle than at the sides of the gully.

The poles from which the brush was trimmed can be used in anchoring a brush dam, especially where rock is encountered in the bottom of the gully and stakes can not be driven. The poles are set diagonally into the lower part of the bank on both sides of the gully, about 3 or 4 feet apart, and bent over to the top of the opposite bank. (Fig. 14.) The larger ends are set into the ground at such an angle that the poles from opposite sides cross 2 or 3 feet

FIGURE 14.—Brush dam anchored with poles under construction in the background, and two completed dams in the foreground. Near Guthrie, Okla.

above the bottom of the gully. The brush is then laid between the lower parts of the poles and under the upper parts, so that when the tops of the poles are bent down it will be held compactly and securely and will be lowest in the middle of the gully. The dam usually extends 10 or 15 feet along the gully. In Figure 15 is a view of a gully reclaimed with brush dams. The filling above the dams was caused by only a few rains.

The average cost of building brush dams 10 to 15 feet long, 2 feet high, and 4 to 6 feet wide, on a soil-erosion experiment farm near Guthrie, Okla., was about $1 for loose-brush dams, and $4 for brush dams anchored with stakes and wire or cross poles. A number of brush dams anchored with poles about 10 feet long, 1 foot high, and 4 feet wide, cost about $1.50 each and several averaging 23 feet long,

3 feet high, and 8 feet wide, cost about $12 each. These costs are based on the actual labor and material required to build the dams and do not include the cost of cutting and hauling the brush to the site of dam, this cost having been charged to the clearing of the land.

In Europe woven-willow dams, sometimes called wattled dams, are rather common and have proved very satisfactory. Live willow stakes about 3 or 4 inches in diameter and 3 to 5 feet long are driven in a row across the gully about 6 inches apart with their tops about 1½ feet above the ground. The row of stakes should extend as far up the sides of the gully as the highest water, and the middle of the

FIGURE 15.—Reclamation of gully by brush dams. The filling above the dams occurred during only a few rains. Near Guthrie, Okla.

dam should be lower than the sides. The stakes are held together by weaving willow branches between them from top to bottom.

As shown in Figure 16, a brush apron is made below the dam to prevent underwashing. This apron is built of branches 6 to 8 feet long laid lengthwise of the gully in a trench about 6 inches deep. The butts of the branches are laid upstream and are partly buried in the bottom of the gully, and the downstream ends are held down by a pole laid across them and spiked to a second row of stakes about 3 feet from the first row. The wattled dam is used to some extent in this country. Pine branches are sometimes used in place of willows.

Another form of brush dam, very common in Europe, is the fascine dam. It is made of bundles of brushwood 8 inches to 2 feet in diameter and from 7 to 14 feet long. The bundles are tied together in several places with wire. They are laid with their length across

the gully and rest against a row of posts set about 3 feet apart. The posts are of the size of ordinary fence posts and are driven or set into the ground at least 4 feet. The bundles are held in place by driving stakes through their centers 1 to 2 feet apart. Trenches are dug into the sides of the gully, and the ends of the bundles are extended into them to prevent washing around the ends of the dam. The dam is made lower in the middle, and an apron of brush to prevent undermining is built below the dam in the manner described for the woven-bush dam. The middle of the dam is 1½ to 2½ feet high.

The brush dam is cheap and easy to build and when carefully and properly constructed is effective in filling gullies. For this reason it is popular among farmers and is employed to some extent in every section of the United States where timber is available. It is best suited for gullies with small drainage areas.

When a farmer has a large quantity of brush to dispose of, a very common practice is to fill the whole length of large, deep gullies with brush which is thoroughly tramped down and sometimes weighted with rock or other heavy material. When the whole gully is filled it is practically impossible for the force of the water to move the brush and the silt is caught and held by the brush as the water flows through. Sometimes sections 25 to 50 feet in length are filled solid with brush at intervals along the gully. The huge dams of brush eventually cause the filling of the gully between. Another practice is to shingle the bottom of the gully with brush (as the roof of a house is shingled), commencing at its lower end and laying the brush with the tops pointing upstream. If the water is likely to dislodge the brush it can be held in place by crosspieces fastened to stakes at intervals along the gully or it can be weighted down with rock. Leaves scattered over the brush assist the catching of silt. After the first layer of brush is covered with silt, other layers can be placed on top until the gully is filled. This practice is especially applicable in filling the lower end of a gully where the fall is not great.

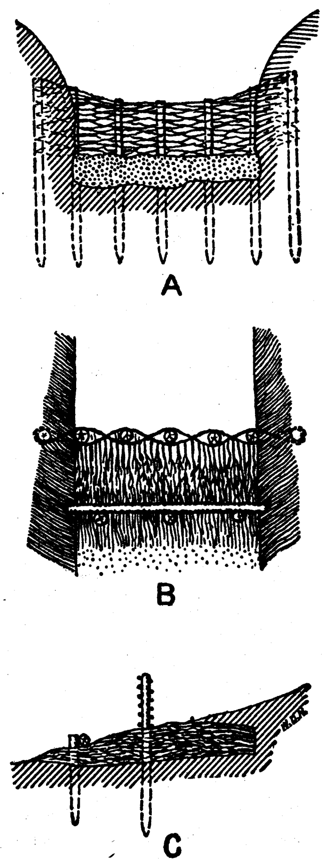

FIGURE 16.—A woven-willow brush dam. A, Front view. B, Top view. C, Side view

WOVEN-WIRE DAM

Like the brush dam, the woven-wire dam is found in every section of the United States. It consists essentially of a low fence across a gully. The posts must be set close together and anchored solidly upstream if the force of the water is great.

The common method of building these dams consists in setting a row of ordinary fence posts across the gully about 4 feet apart. The posts should be set at least 4 feet deep and should be anchored by wire to anchor posts driven 8 or 10 feet above the line of the dam. The deposit of soil caught by the dam later covers these anchor posts and greatly increases their holding power. The end posts should be set in a trench dug into the sides of the gully. The best results are obtained when a trench is dug along the upper side of the posts so that the woven wire may be fastened 6 inches or a foot below the surface. The wire should be at least 30 to 36 inches wide and should be set into the ground so that about 2 feet extend above the surface. The wire is fastened to the upper sides of the posts, and the trench in the sides and across the gully is filled up and carefully tamped. When there is not enough trash in the water

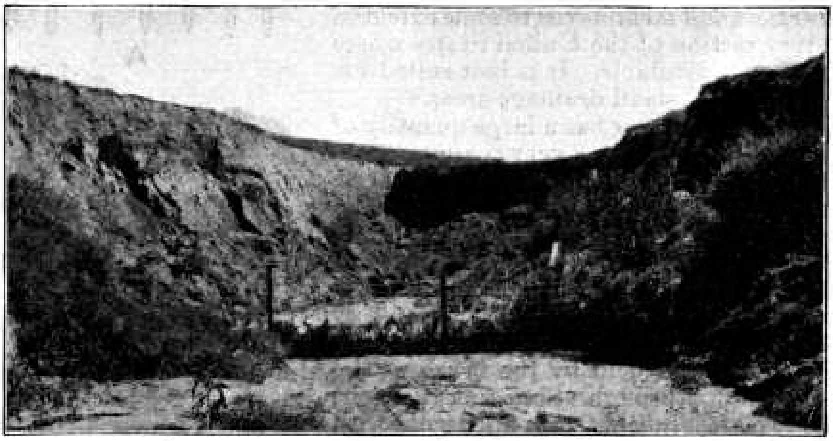

FIGURE 17.—Newly constructed woven-wire-fencing dam built to control erosion at head of gully. Near Alma, Wis.

to close the large meshes in the wire and catch the soil particles, a little straw, leaves, or fine brush can be placed against the upper side of the wire to get a fill started. Angle-iron posts are sometimes used instead of wooden posts. (Fig. 17.)

A dam of this type is especially suitable for use in gullies with moderate slopes and small drainage areas. It is also very effective in checking head erosion at the upper end of a gully.

POLE DAM

Poles from which the brush has been trimmed for brush dams can be used in the construction of pole dams. The poles are laid across the gully in layers, the bottom layer being 2 to 4 feet wide and the top layer one pole wide. The lower poles are laid in a trench one pole deep and extend into the sides of the gully about 2 feet. The poles should be fastened together with spikes and wire. An apron of poles, extending along the gully for a distance of 3 or 4 feet below the dam, is built to prevent the overflowing water from eroding the bottom of the gully and undermining the dam. A notch,

2 to 4 feet wide and 1 to 2 feet deep depending upon the size of the gully, should be left in the center of the dam to permit the water to pass over without eroding the sides. The poles should be laid in grass or straw and earth should be placed and tamped on the upper side of the dam to prevent water from flowing through or around the ends. Figure 18 shows three pole dams in a gully. Most of the silt above these dams was caught during one heavy rain. Actual records show that a pole dam about 1½ feet high at notch and 8 feet wide cost about $4 and 3 feet high at notch and 12 feet wide at top can be built for about $10.

FIGURE 18.—Three pole dams in a gully. Most of the silt above the dams was caught during one heavy rain. Near Guthrie, Okla.

LOG DAM

Where timber is abundant log dams are very commonly built to check gully erosion. The simplest dam for small narrow gullies is made by placing a large log in a shallow trench across the gully. The trench is cut into the sides of the gully so that the ends of the log extend into both sides. Other smaller timbers about 6 or 8 feet long are laid close together lengthwise of the gully, with the downstream ends resting on the log and the other ends on the bottom of the gully above the log. The timbers are spiked to the log. Old railroad ties are sometimes used for the timbers. Dams built in this manner have been very successful in filling gullies that drain small areas.

Another simple type of log dam is built as follows: Posts are set in a row across the gully 4 feet apart, about 4 feet deep, their tops

extending 3 or 4 feet above the bottom of the gully. A trench is then dug on the upstream side of the posts extending about 2 feet into the sides of the gully. A log is laid in this trench, which is just about deep enough to bury it, and other logs are laid on top of the first, until the top log is as high as the top of the posts. The logs are held in place by piling dirt against them, by driving small stakes on the upper side at the ends of the logs, or by spiking them to the posts. A section of the top log between the two posts nearest the center of the dam is cut out to provide a way for the water to flow over the dam and prevent washing around the ends. (Fig. 19.) The bottom of the gully should be paved with stone for about 4 feet below the dam, or may be protected from erosion by laying small logs together as a floor, holding them in place by stakes driven along the lower side. Where rock is plentiful loose rock is placed below the dam to prevent erosion by the falling water. Unless one of the above methods is employed the dam is likely to be undermined.

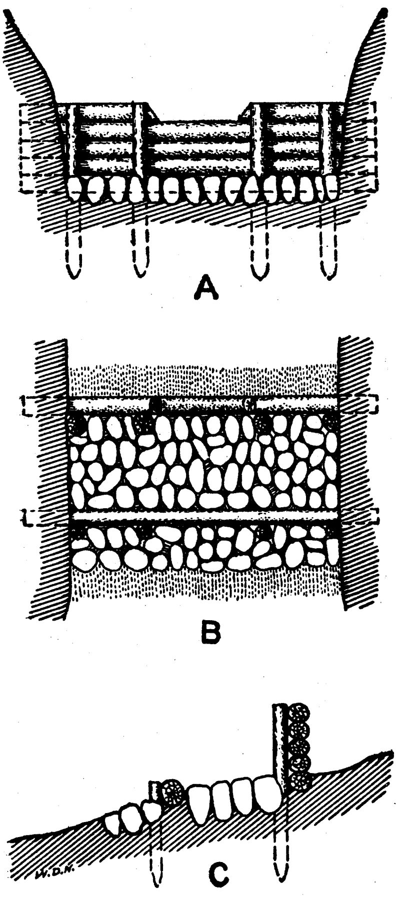

FIGURE 19.—Dam built of logs and posts with spillway at center and stone pavement below the dam: A, Front view; B, top view; C, side view

Where it is difficult to drive or set posts in a gully the logs may be held in place by other logs laid obliquely across them with the ends notched to fit into corresponding notches between the logs of the dam. The free ends of the oblique logs are covered with dirt, and their hold becomes stronger as the fill above the dam grows deeper. (Fig. 20.)

Where both timber and stone are plentiful crib dams are sometimes built. The crib dam consists of a framework or box of logs across the gully, filled with rock fragments or stones. The ends extend into the sides of the gully, and the dam is built in a trench dug across the bottom. Undermining is prevented by a pavement of stone below the dam.

WILLOW-POST DAM

Posts cut from green willow trees are used very effectively to fill gullies. They are set 2 or 3 feet apart in rows across the gully, sometimes several rows of them close together. Where there is

plenty of water the willow posts take root and grow, forming a hedge. Trash and silt are caught above this hedge, causing a fill of soil. Straw or loose, small brush may be thrown above the willows to assist in getting a fill started.

When quicker results are desired, a row of willow posts, 3 or 4 feet apart, is set across the gully, and railroad ties or logs are laid one on top of another above the posts in a manner similar to that described for log dams. Willow dams are usually built at the lower ends of gullies near main water courses or where the soil is naturally moist throughout the year, for the rapid and thrifty growth of willows depends upon abundant water.

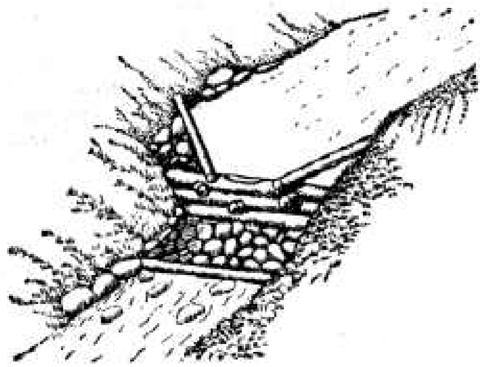
FIGURE 20.—Log dam held by notched logs extending obliquely into the sides of the gully

LOOSE-ROCK DAM

Rock is a very good material for building low soil-saving dams. Its use is particularly advisable on farms where rock is plentiful and often a nuisance in the fields. Loose-rock dams should not be more than 2 to 3 feet high and should be built only in gullies of moderate


FIGURE 21.—Loose-rock dam in highway ditch. Note sediment caught above dam

slope and small drainage areas. The dam should be 4 or 5 feet wide at the base and about 2 feet wide on top. The rock should be so

arranged that the small pieces fit in among the large. Only large pieces should be used on the top of the dam, as a current of water has often sufficient force to move even large stones. The dam should be built well into the banks of the gully and should be lowest in the middle. A trench about 6 inches deep should be dug across the gully, in which the foundation of the dam, consisting of the largest rock, should be laid. The gully below the dam for about 5 feet should be covered with loose rock to prevent erosion and the undermining of the dam. Figure 21 is a view above a loose-rock dam in a highway ditch.

STONE-MASONRY DAM

Masonry dams instead of loose-rock dams are usually built where a greater height than 3 feet is desired, where the flow in the gully is large, or where rock is not plentiful and its economical use is neces-

FIGURE 22.—Masonry dam built across a gully draining over 1,000 acres. This dam extends well into the banks and is lower in the middle than at the ends. Near Kansas City, Mo.

sary. The construction is similar to that of a masonry wall, and the sides should have a batter of 1 in 5 or 1 in 10. The thickness at the bottom should be about one-half the height, and the base should be 1 to 2 feet below the bottom of the gully for dams 3 to 6 feet high. Dams of this kind higher than 6 feet are not recommended unless an excellent foundation is obtained, special precautions taken against undermining, and the walls are extended far enough into the banks of the gully to prevent cutting around the ends. The services of an engineer would be required to build a high masonry dam, and hardly any two gullies would require the same design.

Water may be made to flow over the central portion of dams 3 or 4 feet high by gradually increasing the height of the dam from some point near the middle toward the ends, as shown in Figure 22. Where the ends of the dam are extended well into the banks it is not necessary for the base at the ends to be as low as the base across the gully. Loose rocks should be placed below the dam to prevent washing and undermining.

A dam higher than 4 feet should have a notched spillway in the middle to confine the overflow water to the middle portion of the dam, and a carefully paved floor should be placed below the spillway to prevent undermining by the falling water. Masonry dams more than 3 or 4 feet high are not much used in the reclamation of gullies, owing to the high cost and the difficulty of making them secure.

CONCRETE DAM

Failures of concrete dams are usually the result of poor design and faulty construction. Lack of knowledge of the erosive action of moving water and of the pressure exerted by standing water, and the desire to keep costs low are responsible for many failures.

A spillway should be provided for passing water over the dam,

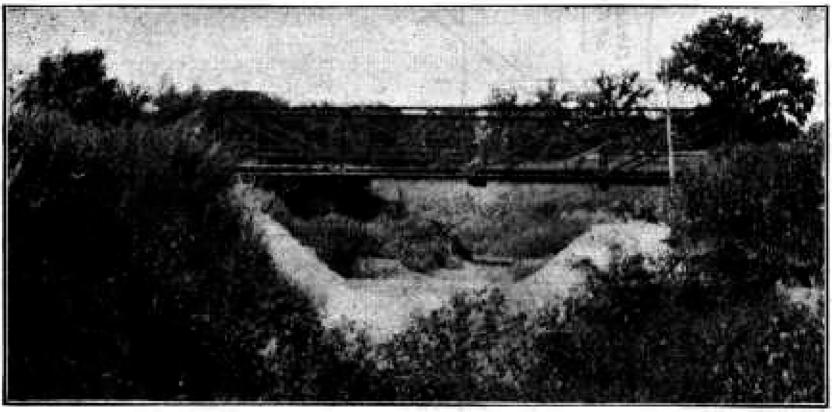

FIGURE 23.—Concrete dam across large gully with ends of dam extending to top of the banks of the gully. This dam was built to fill the gully and prevent enlargement where the highway bridge crosses. A fill of 8 feet has occurred above the dam. Near Mason City, Ill.

usually at the middle, to prevent injury to the structure. If the top of the dam is level, with no spillway, water will flow over the entire dam and will invariably cut away the earth around one or both ends, forming a channel which will allow the accumulated silt to escape. The ends of the dam should extend to the top of the gully, or at least as high as water is expected to rise, to prevent water from coming in contact with the sides of the gully. (Fig. 23.) The ends should extend into the sides of the gully far enough to prevent water from seeping around them and causing a washout.

In Figure 24, are shown the plan, elevation, and side view of a reinforced concrete dam recommended by the agricultural extension department of the Iowa State College. It is claimed for this dam that "it has a firm foundation, extends well into the banks, has an adequate spill platform, * * * and has a means of relieving the water pressure." This design was proposed by the extension department after making comprehensive investigations of concrete dam failures throughout the State of Iowa, and it especially guards against the common causes of failure.

In Figure 25 is shown a series of low reinforced concrete dams employed principally to check erosion. These dams are especially suitable for use in small gullies and roadside ditches with small watershed areas. The wing walls are extended well into the sides of the gully or ditch, and a concrete apron is provided below each dam to prevent undermining.

Concrete dams are built of either plain or reinforced concrete. Dams not exceeding 3 or 4 feet in height are usually built of plain concrete, and higher ones of reinforced concrete. Failures often result from the use of poorly made concrete. A good concrete mixture is 1 part cement, 3 parts sand, and 6 parts stone or broken rock. A competent engineer should be engaged to design and construct a

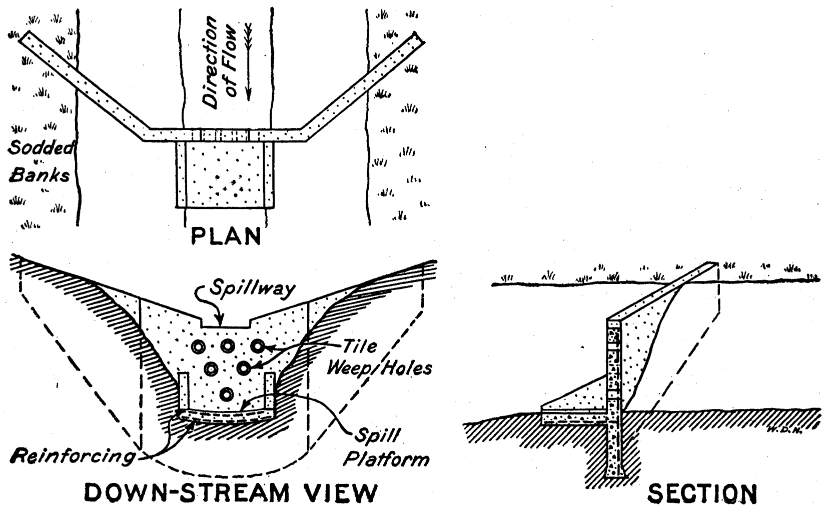

FIGURE 24.—Plan, section, and downstream view of a concrete dam especially designed to guard against the common causes of failure [8]

reinforced concrete dam. No one design is applicable to all conditions.

EARTH DAM

Earth dams of two different types are used. In one type the surplus water is carried around or over the dam by spillways, and in the other it is carried through the dam by a pipe. In many installations the principles of both types are employed. Earth soil-saving dams are generally employed to fill very large gullies, though they are rapidy growing in favor for use in small gullies, particularly where no other cheap material is available for the construction of low dams.

If a spillway is used to carry the water around or over the dam, a pond is formed above the dam, and if the capacity of the pond is not sufficient to hold the greatest run-off from the drainage area the surplus water is conducted through a channel around one end of the dam, or over the dam in a sheet-metal or plank flume. Because of the

[8] From Bulletin 80 of the Iowa State College agricultural extension department.

chances of injury to the dam, the latter method is not recommended, however, unless it is impossible to carry the water around one end of the dam over firm ground.

In the other type of earth soil-saving dam vitrified sewer pipe, corrugated metal pipe, or a rectangular box built of concrete or creosoted lumber is generally used to carry the water through the dam. A cross-sectional view of a dam of this type is shown in Figure 26. Water from heavy rain fills the basin above the dam, the silt settles to the bottom of the basin, and the water flows through the vertical inlet pipe and the pipe through the dam into the gully below. When silt fills the basin to the top of the inlet pipe another section of pipe

FIGURE 25.—Series of reinforced concrete dams used to check erosion in a highway ditch

may be added and the filling continued. The top of the inlet pipe should be at least 3 feet below the top of the dam, and where conditions permit, the top of the dam should be at least 1 foot higher than the firm ground on the sides of the gully after the dam has settled, so that if an unusual rain occurs—heavier than the pipe can handle—the water will flow over the firm ground, not over the top of the dam. The vertical inlet pipe should preferably be set 10 feet or more from the inside toe of the dam, because at that distance it is not likely to become clogged with floating trash that usually accumulates near the dam. Also there is less danger of water eddying around the inlet pipe and causing a break in the dam. The usual practice is to set the inlet pipe close to the dam, because less pipe is required. This practice is no doubt responsible for a great many failures.

Another precaution against possible clogging of the inlet pipe is to wrap ordinary woven fence wire round four posts set around the

pipe, with the bottom of the wire a little lower than the top of the inlet pipe. This permits the water to pass, but keeps out the floating trash. Where it is desired to keep the gully drained above the dam and thus prevent the formation of a pond, the vertical inlet pipe is joined to the horizontal pipe by a tee connection, and to one end of the tee is connected a drain pipe that extends up the gully.

In many instances farmers desire to make the dam serve the double purpose of filling the gully and furnishing a watering place for stock. In such cases an elbow connection is used in place of the tee, or the end of the tee is plugged with a vitrified clay stopper cemented in the pipe. A foundation of stone or concrete should be provided for the tee or elbow of the inlet pipe. The flow of the

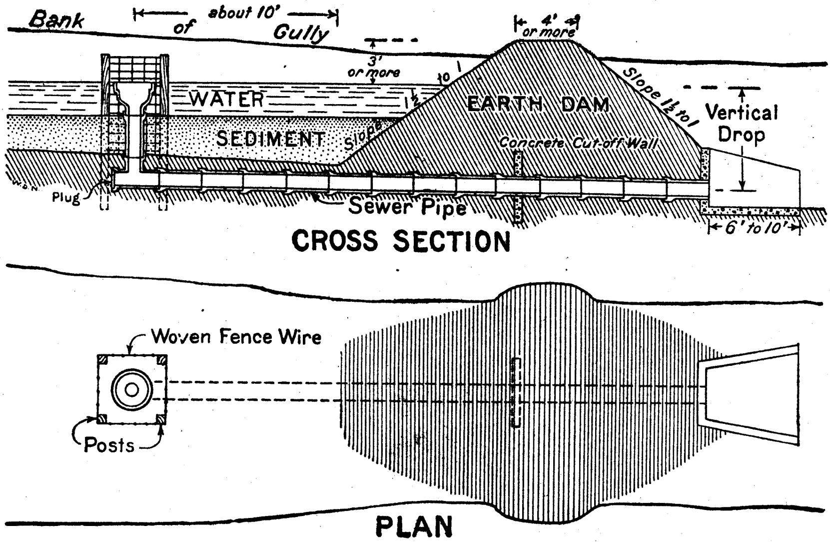

FIGURE 26.—Drop-inlet and earth soil-saving dam

water into the vertical inlet pipe can be facilitated by placing a hopper pipe on top of the vertical inlet. (Fig. 27.)

The pipe through the dam and the joints of the vertical inlet pipe, with the exception of the top joint, should be cemented. Great care should be used in laying the pipe through the dam. A trench with enough fall to prevent water from standing in the pipe should be dug in the bottom of the gully, and holes should be dug under the bell of each pipe so that the barrel rests on firm ground. After the joints are cemented and dried, clay soil should be placed around the pipe and thoroughly tamped. Tamping should be continued over the pipe until it is covered with 2 or 3 feet of soil. Unless the soil forms a close bond with the pipe, water is likely to seep along the pipe and often washes a hole through the dam. (Fig. 28.) Seepage along the pipe can be prevented by building a concrete cut-off wall at the middle of the dam as shown in Figure 26. If a firm and even foundation for the pipe is not obtained, a little unequal settlement due to the weight of the earth above may cause leakage through breaks in the joints of the pipe.

Protection against erosion should be provided where the water discharges from the outlet pipe into the gully below. More important than preventing erosion of the gully below the dam is the prevention of undermining and eating-back through the dam along the pipe. In Figure 26 is shown a channel built of concrete to stop erosion at the outlet of the tile. This channel is usually made 6 to 10 feet long, depending upon the vertical drop of the water. The greater the vertical drop the greater will be the velocity and eroding power of the water. Where it is desired to keep the water out of the gully below the dam the tile can be extended beneath the ground down through the gully to a suitable outlet.

Under Outlets for Soil-Saving Dams (p. 30) the size of out-

FIGURE 27.—Vertical inlet pipe newly constructed, showing hopper pipe on top and end of T plugged with vitrified clay stopper cemented in the pipe. Near Marshall, Mo.

let pipe required is thoroughly discussed, and Table 1 gives the sizes of pipe to use for soil-saving dams. If the pipe is too small, overtopping and washing out of the dam generally occurs.

The foundation of the dam should be prepared by clearing away all weeds, growths, and débris and plowing the site to reduce the possibility of seepage along the bottom of the dam. Another precaution against seepage often advisable, especially where the dam is 10 feet or more in height, is to dig a trench the length of the dam 6 to 10 feet wide and 1½ feet deep. The sides of the trench should be made vertical so as to break the seam between the natural ground and the dam, and the bottom of the trench should be plowed. The dam should be built in layers about 1 foot in depth. It is usually built with teams and scrapers, the material being tamped and compacted by the horses' feet and the scrapers. The best results are

obtained when the loose earth is sprinkled with water, which facilitates the compacting of the embankment and makes it more impervious. The top of the dam should be not less than 4 feet wide, the side slopes on both faces of the dam not less than 1½ horizontal to 1 vertical. The top of the dam should be not less than 3 feet above the bottom of the spillway or top of the vertical inlet pipe. In Figure 26 is shown a section recommended for an earth soil-saving dam.

The best material for building an earth dam consists of 1 part clay to 2 or 3 parts gritty earth. Where water is not available for dampening the material it is best to construct the dam during the rainy season so that the earth in the borrow pit may be kept damp by rains. Material for building dams should preferably be taken from above the dam, 20 to 25 feet above the upstream toe. An allowance of about 10 per cent should be made for the settling of the material in the earth embankment. Where the top of the earth dam is used as a roadway it should be at least 8 feet wide.

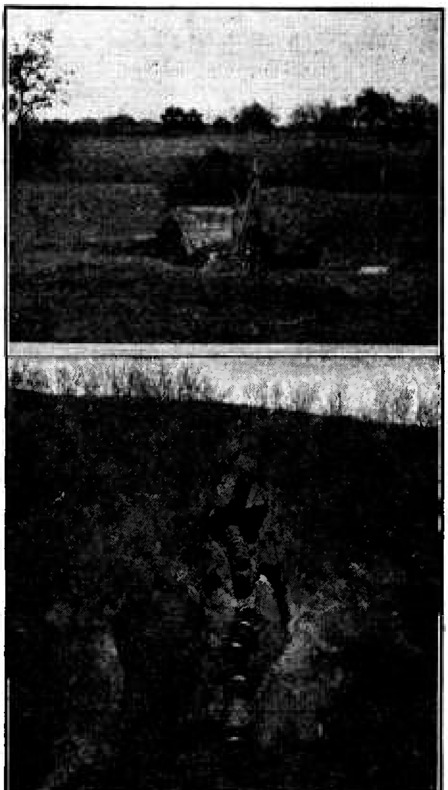

FIGURE 28.—Results of water seeping along outside pipe through a dam

The popularity of the drop-inlet, earth soil-saving dam is growing rapidly. In Saline County, Mo., several hundred have been built, one farmer having 14. In this county they are made in small gullies as well as large, and are placed one above another in the same gully so that the fill from one reaches nearly to the outlet of the next dam above.

DROP-INLET HIGHWAY CULVERTS

Gullies often cause much trouble and expense in building and maintaining public highways. Bridges are required to cross them, and where the gullies are growing wider the length of the bridges must constantly be increased. A notable example is a bridge over a gully near Falls City, Nebr. Thirty-five years ago the gully did not touch the road; since then it has crossed the road and continually widened. A trestle 185 feet long crosses the gully, and its length has been repeatedly increased as the abutments for the approach spans have been undermined by the caving in of the sides of the gully. The drainage area above this bridge is only about 70 acres; the water from this area

could readily be removed by a moderate-sized culvert. In this case further erosion could be stopped by building a road embankment with combined concrete drop inlet and culvert as shown in Figure 29.

In Figure 30 is shown a close view of a concrete drop inlet, and in Figure 31 is shown its design, which was furnished by the county engineer, of Madison County, Iowa. The cover over the drop inlet prevents animals from falling in, but interferes with the flow to some extent. In place of the cover a fence might be built to keep animals out.

Gullies of the waterfall type often eat their way slowly up a watercourse toward a highway. Generally no attempt is made to check the gully until it has reached the road. The usual method then employed to stop it from crossing the roadway is to build a concrete structure to prevent further erosion and the undermining of the roadway and culvert. Figure 2 (p. 2) shows such a struc-

FIGURE 29.—Highway bridge to be replaced by an earth embankment and a combined culvert and concrete drop inlet. Near Winterset, Iowa

ture built at great expense. At the time the picture was taken the structure was partly undermined. About a year after the work was completed the roadway and structure were washed out. The failure was due to a poor foundation and to the fact that the concrete spillway did not extend far enough from the culvert. Where such structures are required they should be properly designed and carefully constructed. It is invariably more satisfactory and less expensive to stop the gully in the farmer's field before it has reached the roadway.

In building a road embankment to cause a fill in the gully above by the use of the drop inlet more care should be taken than in building an ordinary embankment not subject to water pressure from above. The best material should be placed and carefully tamped around the barrel of the culvert and on the upstream side of the embankment. Where there is danger of seepage, one or two concrete cut-off walls should be built around the barrel of the culvert. An installation which has given excellent results is shown in Figure 32.

OUTLETS FOR SOIL-SAVING DAMS

The permanence of a soil-saving dam depends primarily upon the adequacy of the outlet. The outlet may be a spillway that carries the water over or around the end of the dam, a pipe or conduit that carries the water through the dam, or often a combination of the two. The rate at which the water should be carried depends upon the size, shape, and topography of the watershed area, upon the quantity of water that can be stored by the dam, and upon the intensity and amount of heavy rains.

In concrete or masonry structures controlling large drainage areas provision should be made for the water to flow over the entire length of the dam in case of unusually heavy rains. The ends of the dams should be extended as high as the banks of the gully or as high as the highest water expected in the gully.

FIGURE 30.—Drop inlet and box culvert. Plan shown in Figure 31. The old wooden bridge is to be replaced by an earth fill

In the case of earth soil-saving dams a spillway should always be provided around one or both ends of the dam, where possible, by building the top of the dam higher than the natural firm ground on either side of the gully. The greater this height the greater will be the factor of safety against the dam being overtopped and washed out. Spillways built of hard material over the tops of earth dams are not recommended, because of the difficulty of maintaining them and the danger of undermining the dam.

It is important that the pipe through a drop-inlet soil-saving dam be made large enough to remove heavy rainfalls, rapidly enough to prevent overtopping. In Table 1 are given the sizes of pipe or conduit adapted to watersheds with length equal to about twice the width.

In columns 2 and 3 are given the cross-sectional area of a pipe or conduit required for a soil-saving dam with no spillway; where the storage above the dam is very small, as in a narrow valley with a steep slope; and where the drop from the top of the inlet pipe to the center of the outlet end of the pipe through the dam is 4 feet and 8 feet.

In columns 4 and 5 are given cross-sectional areas for conditions similar to those given for columns 2 and 3, except that considerable water is stored above the dam. Such storage considerably reduces the size of pipe required for small watersheds but changes it very little for watersheds 100 acres or more in extent. The area of conduit required can be increased or decreased by increasing or decreasing the storage area.

In columns 6 and 7 are given cross-sectional areas required where the conditions are the same as for columns 4 and 5 except that provision is made to carry part of the flow around the dam over a spill-

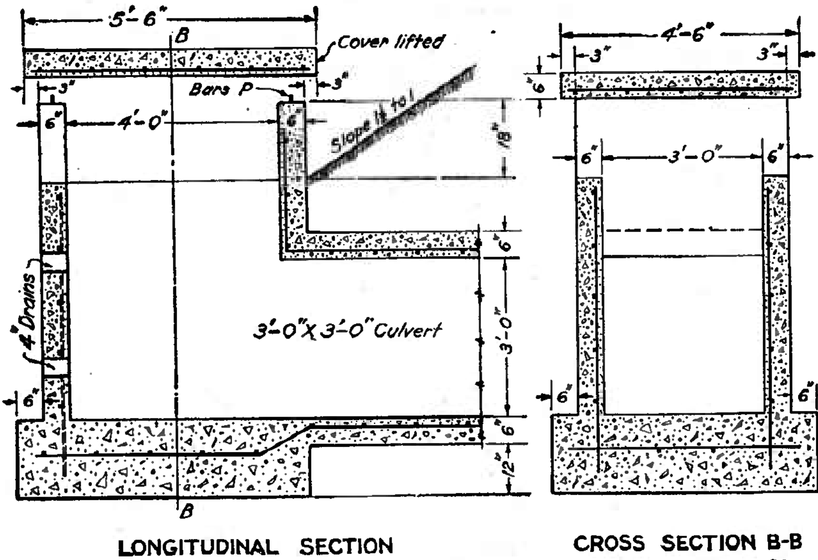

FIGURE 31.—Reinforced concrete drop inlet for box culvert[9] shown in Figure 30

way having a capacity equal to one-half the capacities of pipes or conduits with areas as given in columns 2 and 3.

If the water over the spillway will have a depth of 1½ feet, the cross-sectional area of the flow should be four to eight times the area of a drop inlet that has the same capacity with 4 feet of drop. The farther the water through the spillway must flow to get back into the gully, the larger should be the spillway.

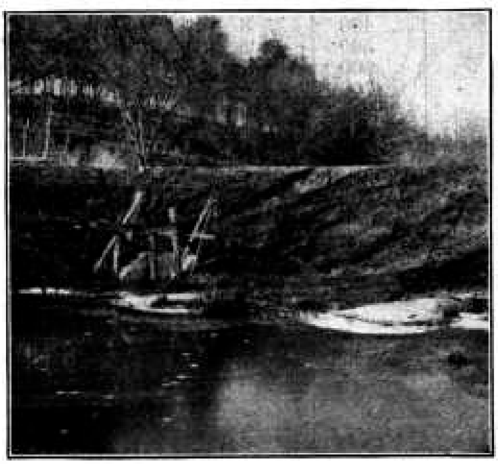

FIGURE 32.—Road embankment and concrete drop inlet replacing an old bridge that was 60 feet long and 35 feet high. Depth of fill is 12 feet. Near Falls City, Nebr.

Suppose it is desired to know the size of a pipe or conduit required for a rolling watershed of 25 acres with length equal to about twice the width, where the surface area of the water stored above the dam would be about one-half acre, where no provision would be made for a spillway round or over the dam, and where the vertical drop from the

[9] Designed by E. B. Hiatt, of Winterset, Iowa.

TABLE 1.—*Cross-sectional areas of pipe or conduit for drop-inlet, soil-saving dams for rolling watersheds with length equal to about twice the width*

Drainage area	With no spillway around or over dam: Very little storage above dam, 4-foot drop	With no spillway around or over dam: Very little storage above dam, 8-foot drop	With no spillway around or over dam: Storage above dam, surface area, ½ acre at level of top of inlet pipe, 4-foot drop	With no spillway around or over dam: Storage above dam, surface area, ½ acre at level of top of inlet pipe, 8-foot drop	With spillway having capacity about half that of pipe in column 2; storage, ½ acre at level of top of inlet pipe, 4-foot drop	With spillway having capacity about half that of pipe in column 2; storage, ½ acre at level of top of inlet pipe, 8-foot drop
Acres	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*
1	0. 4	0. 3	0. 2	0. 1	0. 05	0. 0
2	. 7	. 5	. 35	. 2	. 1	. 0
4	1. 1	. 8	. 6	. 3	. 15	. 0
6	1. 5	1. 1	. 8	. 5	. 2	. 0
8	1. 9	1. 4	1. 1	. 65	. 25	. 0
10	2. 2	1. 7	1. 3	. 8	. 30	. 0
15	3. 0	2. 3	2. 0	1. 2	. 4	. 1
20	3. 8	2. 8	2. 7	1. 7	. 5	. 2
25	4. 5	3. 4	3. 4	2. 2	1. 1	. 3
30	5. 1	3. 8	3. 9	2. 6	1. 2	. 5
35	5. 8	4. 3	4. 5	3. 1	1. 5	. 7
40	6. 3	4. 8	5. 1	3. 5	1. 8	1. 0
45	6. 9	5. 2	5. 7	4. 0	2. 2	1. 2
50	7. 5	5. 6	6. 3	4. 4	2. 6	1. 5
60	8. 6	6. 5	7. 6	5. 4	3. 2	2. 2
70	9. 7	7. 3	8. 6	6. 2	3. 7	2. 5
80	10. 7	8. 0	9. 6	6. 9	4. 2	2. 9
90	11. 7	8. 8	10. 6	7. 7	4. 8	3. 3
100	12. 6	9. 5	11. 6	8. 4	5. 3	3. 7
125	15. 0	11. 2	14. 1	10. 4	6. 7	4. 8
150	17. 2	12. 9	16. 7	12. 4	8. 2	6. 0
175	19. 2	14. 4	19. 2	14. 4	9. 6	7. 2
200	21. 3	16. 0	21. 3	16. 0	10. 6	8. 0
300	28. 8	21. 6	28. 8	21. 6	14. 4	10. 8
400	35. 8	26. 8	35. 8	26. 8	17. 9	13. 4
500	42. 3	31. 7	42. 3	31. 7	21. 1	15. 8
600	48. 5	36. 4	48. 5	36. 4	24. 2	18. 2
700	54. 4	40. 8	54. 4	40. 8	27. 2	20. 4
800	60. 2	45. 2	60. 2	45. 0	30. 1	22. 5
900	65. 7	49. 3	65. 7	49. 2	32. 8	24. 6
1, 000	71. 1	53. 3	71. 1	53. 3	35. 6	26. 6

For very hilly watersheds increase above cross-sectional areas 25 per cent.
For square or fan-shaped watersheds increase above cross-sectional areas 15 per cent.
For sizes of pipes corresponding to the above cross-sectional areas see Table 2.

TABLE 2.—*Cross-sectional areas of pipes of standard diameters for use in selecting sizes corresponding to areas in Table 1*

Diameter of pipe	Cross-sectional area of pipe	Diameter of pipe	Cross-sectional area of pipe
Inches	*Square feet*	*Inches*	*Square feet*
6	0. 20	27	3. 98
8	. 35	30	4. 91
10	. 55	33	5. 94
12	. 79	36	7. 07
15	1. 23	39	8. 30
18	1. 77	42	9. 62
21	2. 41	45	11. 04
24	3. 14	48	12. 57

top of the inlet to the outlet end of the pipe would be 8 feet. In the first column in Table 1, under Drainage area in acres, find 25, then follow the line across the page to the right to the fifth column, which falls under three heads at the top of the table. First, no spillway round or over the dam; second, storage above dam, surface area one-half acre at level of top of inlet pipe; third, 8 feet drop. The number in the fifth column is 2.2, which means that the pipe through the dam should have an area of 2.2 square feet. In Table 2 it is found that an 18-inch pipe has a cross-sectional area of 1.77 square feet, and a 21-inch pipe 2.41 square feet. A 21-inch pipe should be chosen, since no smaller standard-sized pipe has the required area.

Where several drop-inlet soil-saving dams are built in a gully, the outlet pipe for the upper dam should be chosen as explained above. The size of the outlet pipe for the next dam below will depend upon several governing conditions: (1) If the storage above the upper dam and the additional watershed area drained by the gully between the dams is negligible, the outlet pipe for the lower dam should be of the same size as for the upper dam; (2) if the storage above the upper dam is negligible and there is a large additional watershed area between the dams, then the size of the outlet pipe should be chosen from Table 1 for the total watershed area above the lower dam; (3) if there is considerable storage above the upper dam and a negligible watershed area between the dams, the pipe for the lower dam might be smaller than for the upper dam, yet on account of the difficulty of ascertaining just how much smaller the pipe could be, a safer practice would be to use the same size of pipe for both dams; (4) if there is considerable storage above the upper dam and a large watershed area between the dams, the outlet pipe should be chosen from Table 1 for a watershed equal to the sum of the watershed area between dams and a certain part of the watershed area above the upper dam, depending upon the reduction in flow effected by the upper dam storage. It is impossible to say just what part of the upper watershed should be included, since hardly any two cases would be similar, but this information can be obtained from an engineer after an examination of the watersheds and the dam sites.

The waterway through the dam may be a pipe or a concrete box. Standard vitrified clay sewer pipe can be obtained up to 36 inches and concrete pipe up to 48 inches in diameter. Where a cross section greater than that of a 36 or 48 inch pipe is required a concrete conduit of the required cross-sectional area can be built.

Where the outlet pipe is extended down the gully as an underdrain, a very good practice since it prevents erosion at the outlet and in the gully below, a somewhat larger tile would be required than that indicated in Table 1. The size of such a tile should be determined by an experienced engineer.

HOW TO RECLAIM A GULLY WITH SOIL-SAVING DAMS

Before work is begun, a plan should be decided upon for the reclamation of the entire gully. Too often a small section is reclaimed in a way which will not fit into any later scheme for the

reclamation of the whole gully. Work should begin at the upper end, where head erosion is going on. This should be stopped by building an overfall of brush and straw, as has been described, by constructing a flume to conduct the water into the gully without erosion, or by the diversion of the water from the head of the gully.

Next, plans should be made for filling the gully. If it decreases gradually in depth toward the lower end and terminates in a wide shallow depression, a number of low temporary dams can be used. If the gully terminates in the side of a deep drainage channel, however, the lower end can not be filled by a low dam, and a high one must be built where the gully enters the channel. Unless conditions make it necessary to use high dams, low dams should be built, even though more of them are required to reclaim the gully, since the cost will be less and low dams are much less subject to failure.

Often the erosion of soil from the watershed is very slight, and a number of years would be required to fill the gully. This is especially true where the watershed is in pasture, meadow, or timber. In such cases a series of dams of the overflow type should be built, so that some silt will be caught above each one, or a dam may first be built at the lower end of the gully and other dams built later in succession above, after the gully is partly filled in. The side slopes of the gully should be plowed in, so that farming operations can be conducted in and across the gully.

Some gullies occur in the natural channels of fields and have large drainage areas, while others occur on the slope of a hillside with very small drainage areas which are not well defined. Gullies of the latter type may be entirely filled and then prevented from washing out by proper cultural methods or by terracing. Gullies with large well-defined drainage areas can not be entirely filled, since it is necessary to leave a waterway large enough to carry off the water. A very common mistake is so to reduce the size of the waterway by filling in the gully that the drainage water overflows its banks; this often proves disastrous to reclamation works. The size of the waterway that should be left can be judged from the high-water flow in the gully.

SPACING DAMS IN A GULLY

In reclaiming the whole length of a gully a series of dams is built, the distance between the dams depending upon their height and the slope of the gully. The less the slope of the gully or the greater the height of the dam the greater may be the distance between the dams. Usually the dams should be so spaced that the fill that accumulates to the top of one extends to the foot of the next above. A dam will cause a fill that is higher at some distance above than at its foot. The fall of the surface of the fill in the gully will not much exceed 6 inches in 100 feet, and in computing the distance between dams so that the fill will extend from the top of one dam to the foot of the next this rate of fall has been assumed and values for Table 3 were computed accordingly. The table gives the dis-

tances between dams ranging from 2 to 10 feet in height in gullies with falls ranging from 2 to 20 feet in 100 feet.

TABLE 3.—*Distances between dams in gullies for dams of various heights and gullies of various bottom slopes*

Height of dam	Bottom slope of gully: 2 feet in 100 feet	5 feet in 100 feet	10 feet in 100 feet	15 feet in 100 feet	20 feet in 100 feet
	Distances between dams				
Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
2	133	44	21	14	10
3	200	67	32	21	15
4	267	89	42	28	20
5	333	111	53	34	26
6	400	133	63	41	31
7	467	156	74	48	36
8	533	178	84	55	41
9	600	200	95	62	46
10	667	222	105	69	51

Sometimes there are contracted sections in gullies that are naturally suitable for the location of dams. Under such circumstances it may be desirable to disregard the spacing as given in the table and build the dams high enough to conform to the spacing naturally suggested. With the actual distances between the dams determined, the required heights can be taken from the table.

As a general rule it is cheaper and more satisfactory to reclaim gullies with low rather than with high dams. A low dam costs considerably less and requires less care and attention than a high dam.

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